Fermilab

Directorate

TECHNICAL SCOPE OF WORK
FOR THE 2015 FERMILAB TEST BEAM FACILITY PROGRAM

T-1064

STAR Forward Calorimeter System

February 10, 2015

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INTRODUCTION

This is a technical scope of work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of University of California – Berkeley, Brookhaven National Laboratory, Kent State University and the University of Science and Technology of China who have committed to participate in beam tests to be carried out during the 2015 Fermilab Test Beam Facility program.

The TSW is intended primarily for the purpose of recording expectations for budget estimates and work allocations for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to modify this scope of work to reflect such required adjustments. Actual contractual obligations will be set forth in separate documents.

This TSW fulfills Article 1 (facilities and scope of work) of the User Agreements signed (or still to be signed) by an authorized representative of each institution collaborating on this experiment.

Description of Detector and Tests:

The STAR forward calorimetry group wishes to study the energy resolution of some recently modified cells from the AGS E864 Calorimeter. The E864 cells consist of 47 layers of 2mm sheets of Pb with 47 equally spaced scintillating fibers captured between each layer (see figure).

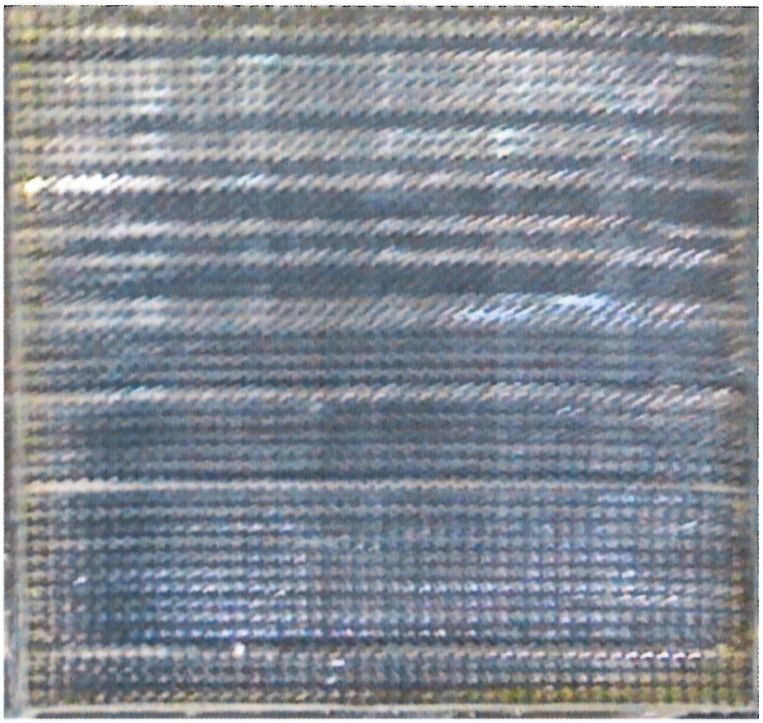


Figure 1: End on view of E864 Calorimeter Cell

The result is a 10cm2 x 117cm cell module weighing in at 110kg (see figure 2).

Figure 2: Pb-scintillator cell as constructed by E864 collaboration

Complete details of the E864 cell construction can be found at https://www.phenix.bnl.gov/WWW/publish/johnson/FHC/docs/864calorimeter.pdf

For E864 and in the recent AnDY experiment (http://arxiv.org/pdf/1109.0650.pdf) at RHIC these modules were viewed end on with a 2" Philips XP 2262B. For the AnDY experiment an array of unmodified calorimeter cells was used in the 2011 & 2012 runs to measure $\pi^0 \rightarrow \gamma\gamma$ for which a ~8%/√E resolution was obtained. Owing to the excellent craftsmanship and attention to detail by the fabricators, the distribution of fibers in each calorimeter module is extremely uniform. In an effort to improve both the position and electromagnetic resolution, the single light guide and 2"pmt have been replaced with nine (9) individual light guides and 1" pmts (see figure 3).

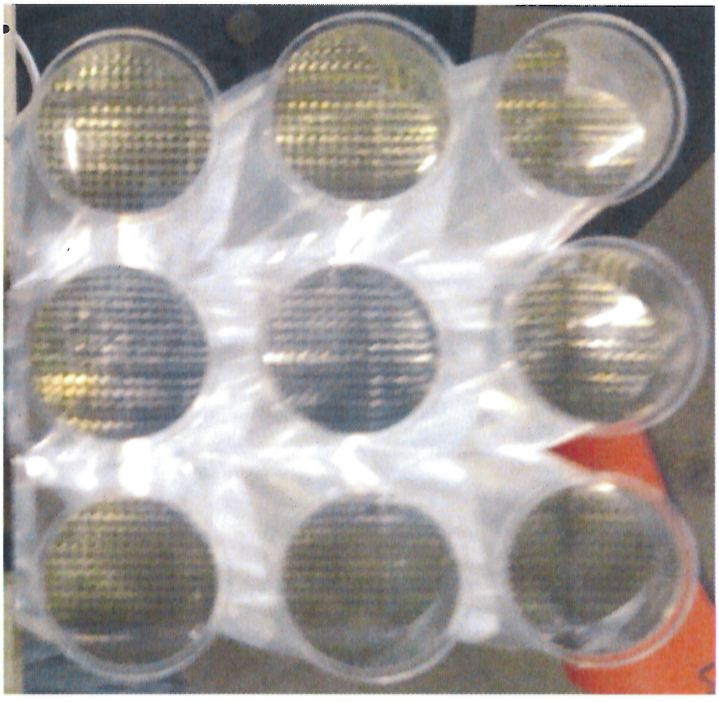


Figure 3: end on view of pixelized E864 Calorimeter Cell

This replaces the single $10x10cm^2$ cell with nine $3.3cm^2$ cells (see figure 2), gaining an increase in position resolution, and because of the 2.5cm Moliere radius, an increase in the electromagnetic energy resolution is expected. This is what the STAR group wishes to test.

For the test the experimenters plan to assemble a 2x2 array of the modified E864 cells on a Fermilab supplied motion table. The STAR group will supply the necessary electronics and data acquisition system similar to what is being used in the STAR experiment at RHIC. The STAR group hopes to take advantage of existing beam monitoring equipment in the MT6.2 line.

Tests include: radiating cell with electrons and pions of known and similar energies and mapping across the 10x10cm cell face to determine changes in efficiency.

The goal is to verify that the modified cell achieves the resolution needed to function as a combination electromagnetic and hadronic calorimeter at the RHIC STAR experiment. If successful, the experimenters propose to install 316 of these pixelized colorimeter cells in the forward direction in the STAR experiment at RHIC. The resulting FCS will be used in the investigations of the internal structure of nucleons and nuclei through analysis of di-jet mass spectra and Drell-Yan e^+e^- pairs produced in pp and PA collisions at 200GeV and 500GeV (http://hena.lbl.gov/FMS/docs/FHC_proposal_140519.pdf). The ability to determine and distinguish the shower shapes for pions and electrons to help with hadron rejection is an important part of the Drell-Yan program.

I. PERSONNEL AND INSTITUTIONS:

Spokesperson: Hank Crawford

Lead Experimenter in charge of beam tests: Jack Engelage

Fermilab Experiment Liaison Officer: Aria Soha

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	University California - SSL	USA	Hank Crawford	Senior Staff Scientist	STAR
			Chris Perkins	Design Engineer	STAR
			Jack Engelage	Project Scientist	STAR
			Eleanor Judd	Staff Scientist	STAR, EUSO
1.2	Brookhaven National Lab	USA	Les Bland	Staff Scientist	STAR
1.3	Kent State Univ	USA	Prashanth Shanmuganathan	Graduate Student	STAR
1.4	UTSC	China	Zebo Tang	Professor	STAR

II. Experimental Area, Beams and Schedule Considerations:

2.1 Location

2.1.1 The beam test(s) will take place in MT6.2-B due to the weight of the detector.

2.1.2 Work space is needed outside the MT6.2-B area to stage the 2x2 array and test with cosmic rays before rigging into position at MT6.2

2.2 Beam

2.2.1 Beam Types and Intensities

Energy of beam: 30 GeV, 10 GeV
Particles: pions, electrons, muons
Intensity: 1k – 10k particles/ 4 sec spill
Beam spot size: less than or equal to ~1 cm^2

2.2.2 Beam Sharing

Upstream: The STAR FCS test is compatible with thin upstream experiments during tune up. During calibration running we would request any mass upstream be minimal and uniform in charge and density.

Downstream: At over 200 radiation lengths the calorimeter modules are probably not compatible with any experiment setups placed downstream of the FHC array.

2.3 Experimental Conditions

2.3.1 Area Infrastructure

The FCS detector will consist of four (4) 10x10x220cm Pb-scintillator modules (see https://www.phenix.bnl.gov/WWW/publish/johnson/FHC/docs/864calorimeter.pdf) stacked into a 2x2 array. FCS will present a 40cm x 40cm area to the beam, have a 90cm x 150cm footprint, and weigh ~500Kg.

The FCS will be assembled on a Fermi lab provided 1500lbs (686KG) capacity motion table. No tracking or special cooling or power (other than <20A of 120 VAC) are required.

No Gas is required for FCS detector nor electronics

2.3.2 Electronics and Computing Needs

The experimenters will be bringing the following commercial electronics:

MVME 2306	http://www.mvme.com/mvme2306.html
BeagleBone	www.beaglebone.org
Wiener 9uVME crate	http://www.wiener-d.com/sc/powered-crates/vme/
Supermicro Computers (linux)	
3035B Tektronic Oscilloscope	www.tek.com
NPS network power supply	http://www.wti.com/p-33-nps-115-remote-telnet-network-power-switch.aspx

The experimenters will be bringing the following non-commercial electronics:

PMT bases	http://hep.uchicago.edu/~rosner/p226/cw1.pdf	
QT/QT-Boc	http://www.star.bnl.gov/public/trg/CTB/Schematics/QT8b_schematic.pdf http://www.star.bnl.gov/public/trg/CTB/Schematics/QT32b_schematic.pdf http://www.star.bnl.gov/public/trg/CTB/Schematics/qt32boc.pdf	
DSM/DSMI	http://www.star.bnl.gov/public/trg/TSL/Schematics/TRG400.pdf http://www.star.bnl.gov/public/trg/TSL/Schematics/TRG401.pdf	
TCU/TCUI	http://www.star.bnl.gov/public/trg/TSL/Schematics/TCU2008-A-Patched.pdf http://www.star.bnl.gov/public/trg/TSL/Schematics/TRG501.pdf	
STP	http://www.star.bnl.gov/public/trg/TSL/Schematics/STP_Concentrator_schematic.pdf	
PHENIX LVDM	http://startrg.lbl.gov/IP2/Business/electronics/PMT_Interface_Channel.pdf http://startrg.lbl.gov/IP2/Business/electronics/DVCBschematic.pdf	
SiPM FEEs	http://npvm.ceem.indiana.edu/~gvisser/STAR/FPS/drawings/4030033_STAR_FPS_FEE_sch.pdf	
RCC/RCF	http://www.star.bnl.gov/public/trg/TSL/Schematics/RCC2b-030812-patched.pdf http://www.star.bnl.gov/public/trg/TSL/Schematics/RCF2-C-051612.pdf	

Note all electronics, including non-commercial, have passed safety reviews at BNL and have been in service at RHIC for a number of years without incident.

The experimenters will borrow a NIM bin and two (2) full size electronics racks (See Appendix II for summary of PREP equipment pool needs).

The FCS Run Control computer will need access to the outside world. This will be the only computer other than personal laptops that will need to be connected to the Fermilab network. Other computers and smart devices used in acquiring data or controlling electronics will be on a private network accessible only via the run control machine.

2.3.3 Description of Tests

General Run Plan:

- First two days will be taken up with
    1. Finishing whatever safety and orientation instructions that cannot be done online.
    2. Unpacking, obtaining local equipment, positioning detector on motion table, assembling/checkout of electronics
    3. Test with cosmic rays
- Once equipment is installed and working
    1. Learn beam operations and operation of X-Y motion table
    2. Use the X-Y motion table to scan the beam across all 36 pixels in 2x2 array for a few thousand events per pixel
    3. Adjust gains and repeat scan.
    4. Once gain is set, repeat scan for ~10k events per pixel
    5. Rotate 2x2 array ~10 degrees and repeat scan
    6. Change energies and repeat steps 1->5
    7. Change ion species and repeat steps 1->6

The experimenters expect infrequent access to rotate the detector or fix any minor problems that cannot be cleared remotely.

2.4 SCHEDULE

Experimental Planning Milestones

Monday May 4, 2015	Arrive, interface with local support, locate equipment	
Tuesday May 5	Train, begin staging calorimeter	
Wednesday May 13	Take beam	
Tuesday May 19	Begin disassembling equipment	
Wednesday May 20	Finish disassembly and pack	
Friday May 22	Ship equipment and depart	

The FCS team requests 2 weeks of time in the MT2-B area: 1 week to setup the detector and 1 week of beam for data taking. This 2 week period should suffice for completing all the FCS tests and a return is not anticipated.

III. Responsibilities by Institution – Non Fermilab

3.1 Brookhaven National Laboratory

- Responsible for supplying E864 Modules including support Low Voltage and LED systems

3.2 Kent State University

- Expertise in assembling and running FCS detector

3.3 University of California – Space Sciences Lab

- Responsible for providing and maintain data acquisition and electronics

3.4 University of Science and Technology of China (USTC)

- Responsible for providing SiPMs and lightguides

3.5 University of Indiana

- Responsible for providing SiPM electronics

IV. Responsibilities by Institution – Fermilab

4.1 Fermilab Accelerator Division:

4.1.1 Use of MTest beamline as outlined in Section II. [0.25 FTE/week]
4.1.2 Maintenance of all existing standard beam line elements (SWICs, loss monitors, etc) instrumentation, controls, clock distribution, and power supplies.
4.1.3 Scalers and beam counter readouts will be made available via ACNET in the MTest control room.
4.1.4 Reasonable access to the equipment in the MTest beamline.
4.1.5 Connection to ACNET console and remote logging should be made available.
4.1.6 The test beam energy and beam line elements will be under the control of the AD Operations Department Main Control Room (MCR). [0.25 FTE/week]
4.1.7 Position and focus of the beam on the experimental devices under test will be under control of MCR. Control of secondary devices that provide these functions may be delegated to the experimenters as long as it does not violate the Shielding Assessment or provide potential for significant equipment damage.
4.1.8 The integrated effect of running this and other SY120 beams will not reduce the neutrino flux by more than an amount set by the office of Program Planning, with the details of scheduling to be worked out between the experimenters and the Office of Program Planning.

4.2 Fermilab Particle Physics Division:

4.2.1 The test-beam efforts in this TSW will make use of the Fermilab Test Beam Facility. Requirements for the beam and user facilities are given in Section II. The Fermilab PPD DDO Test Beam Group will be responsible for coordinating overall activities in the MTest beam-line, including use of the user beam-line controls, readout of the beam-line detectors, and FTBF computers. [6.5 FTE/week]
4.2.2 Provide 1500lbs (686KG) capacity remote controlled motion table and 20A of 110VAC power for experimenters' electronics.
4.2.3 Provide rigging help to position the 2x2 array on XY-motion table
4.2.4 Conduct a NEPA review of the experiment.
4.2.5 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.
4.2.6 Provide safety training as necessary, with assistance from the ESH&Q Section.
4.2.7 Update/create ITNA's for users on the experiment.
4.2.8 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews.

4.3 Fermilab Scientific Computing Division

4.3.1 Internet access should be continuously available in the MTest control room.
4.3.2 See Appendix II for summary of PREP equipment pool needs.
4.3.3 Provide the following computing needs: [0.2 FTE]
4.3.3.1 Ethernet connection for experimenters' run control computer to allow connections to outside FermiLab.

4.3.3.2 Ethernet (wifi?) connections for experimenters' laptops to allow connection to Experimenters' run control computer while at FermiLab

4.3.3.3 Computer accounts for experimenters if necessary for them to reach run control computer from outside FermiLab

4.4 FERMILAB ESH&Q SECTION

4.4.1 Assistance with safety reviews.

4.4.2 Provide safety training, with assistance from PPD, as necessary for experimenters. [0.2 FTE]

4.4.3 Comment from Eric McHugh: "**Looking at the photos, looks as though the paint may be coming off exposing the lead substrate. If that is the case, they should encapsulate that somehow. Tape or other means to prevent lead transfer to our equipment.**"

V. Summary of Costs

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Accelerator Division	0	0.5
Particle Physics Division	0.0	6.5
Scientific Computing Division	0	0.2
ESH&Q Section	0	0.2
Totals Fermilab	$0.0K	7.4
Totals Non-Fermilab	[specify from Section III]	[specify]

VI. General Considerations

6.1 The responsibilities of the Spokesperson and the procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Researchers": (http://www.fnal.gov/directorate/PFX/PFX.pdf). The Spokesperson agrees to those responsibilities and to ensure that the experimenters all follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ESH&Q) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the Division's Safety Officer.

6.3 The Spokesperson will ensure at least one person is present at the Fermilab Test Beam Facility whenever beam is delivered and that this person is knowledgeable about the experiment's hazards.

6.4 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ESH&Q section.

6.5 All items in the Fermilab Policy on Computing will be followed by the experimenters. (http://computing.fnal.gov/cd/policy/cpolicy.pdf).

6.6 The Spokesperson will undertake to ensure that no PREP or computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Scientific Computing Division management. The Spokesperson also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Sector management.

6.7 The experimenters will be responsible for maintaining both the electronics and the computing hardware supplied by them for the experiment. Fermilab will be responsible for repair and maintenance of the Fermilab-supplied electronics listed in Appendix II. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

6.8 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters' Meeting.

6.9 The Spokesperson is the official contact and are responsible for forwarding all pertinent information to the rest of the group, arranging for their training, and requesting ORC or any other necessary approvals for the experiment to run.

6.10 The Spokesperson should ensure the appropriate people (which might be everyone on the experiment) sign up for the test beam emailing list.

6.11 The spokesperson, or designee, will generate a one-page summary of the experiment's use of the Test Beam facility during the fiscal year, to be included in the annual Test Beam Report Fermilab submits to the DOE.

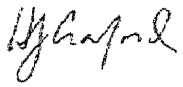
At the completion of the experiment:

6.12 The Spokesperson is responsible for the return of all PREP equipment, computing equipment and non-PREP data acquisition electronics. If the return is not completed after a

period of one year after the end of running the Spokesperson will be required to furnish, in writing, an explanation for any non-return.

6.13 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ESH&Q requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters unless removal requires facilities and personnel not able to be supplied by them, such a rigging, crane operation, etc.

SIGNATURES:



2 Dec 2014

H.J.Crawford, Experiment Spokesperson

APPENDIX I: MT6 AREA LAYOUT

MTEST AREAS

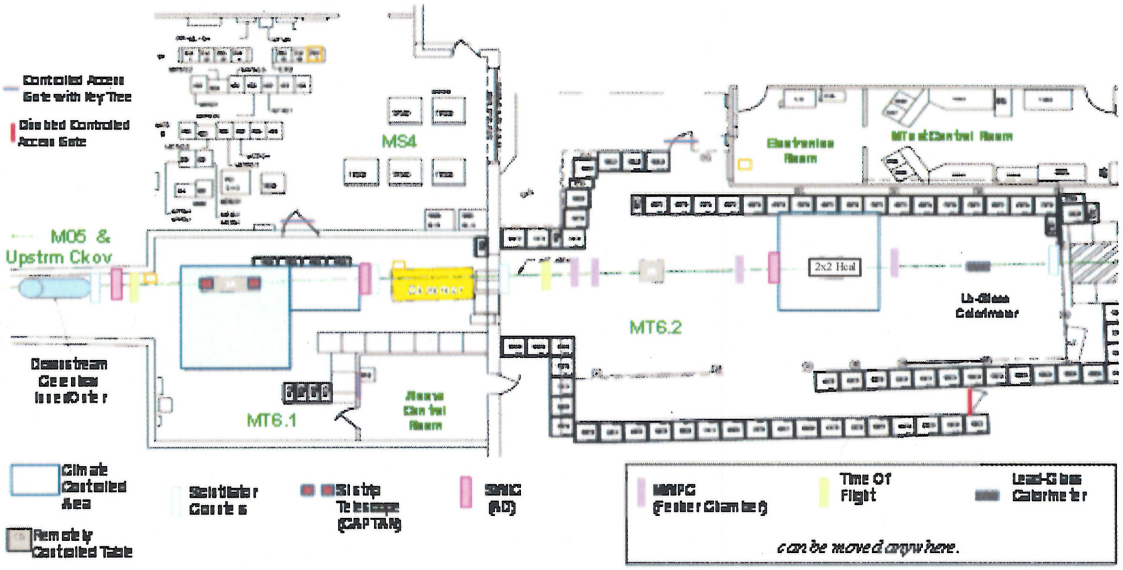


Figure 4: shows position of 2x2 array of HCal Cells on Remotely Controled Table in MT6.2 area

APPENDIX II: EQUIPMENT NEEDS

Provided by experimenters:

Equipment Pool and PPD items needed for Fermilab test beam, on the first day of setup.

PREP EQUIPMENT POOL:

Quantity	Description
1	NIM bin

PPD FTBF:

Quantity	Description
1	connection to network
2	electronics racks (full size)

APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked.
See ORC Guidelines for detailed descriptions of categories.

Flammables (Gases or Liquids)		**Gasses**		**Hazardous Chemicals**		**Other Hazardous /Toxic Materials**
Type:		Type:			Cyanide plating materials	List hazardous/toxic materials planned for use in a beam line or an experimental enclosure:
Flow rate:		Flow rate:			Hydrofluoric Acid	
Capacity:		Capacity:			Methane	
Radioactive Sources		**Target Materials**			photographic developers	
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:			Mercury (Hg)		TEA	
Strength:		X	Lead (Pb)		TMAE	
Lasers			Tungsten (W)		Other: Activated Water?	
	Permanent installation		Uranium (U)			
	Temporary installation		Other:	**Nuclear Materials**		
	Calibration	**Electrical Equipment**		Name:		
	Alignment		Cryo/Electrical devices	Weight:		
Type:			Capacitor Banks	**Mechanical Structures**		
Wattage:			High Voltage (50V)		Lifting Devices	
MFR Class:			Exposed Equipment over 50 V		Motion Controllers	
		X	Non-commercial/Non-PREP		Scaffolding/ Elevated Platforms	
			Modified Commercial/PREP		Other:	
Vacuum Vessels		**Pressure Vessels**		**Cryogenics**		
Inside Diameter:		Inside Diameter:			Beam line magnets	
Operating Pressure:		Operating Pressure:			Analysis magnets	
Window Material:		Window Material:			Target	
Window Thickness:		Window Thickness:			Bubble chamber	

The following people have read this TSW:

Patty McBride, Particle Physics Division, Fermilab — 3 / 18 / 2015

Sergei Nagaitsev, Accelerator Division, Fermilab — 3 / 17 / 2015

Martha Michels, ESH&Q Section, Fermilab — 3 / 17 / 2015

Robert Roser, Chief Information Officer, Fermilab — 3 / 18 / 2015

Joe Lykken, Chief Research Officer, Fermilab — 3 / 19 / 2015